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ABSTRACT

In order for the United States to hold its long-standing position as an international leader in research and development, current as well as future generations must be made aware of the relationship between basic research and improvements in the quality of life. Seven subcommittees were asked to present overviews and discussions of their perspectives, issues, and recommendations to the U.S. Public Health Service (PHS). The issues are as follows: (1) "Public Awareness" suggests how PHS can improve public understanding of biomedical and behavioral research and its implications for individuals and society; (2) "Teacher Education" identifies mechanisms through which PHS can help improve the preservice and inservice education of teachers; (3) "Curriculum Development" suggests how PHS can help develop and implement science curriculums that will insure there is a pool of well-prepared biomedical and behavioral scientists, and identify how PHS can contribute to general scientific literacy; (4) "Student Incentives" suggests how PHS can attract students to and retain their interest in the study of life sciences; (5) "Underrepresented and Underserved Groups" suggests mechanisms that help PHS attract and retain underrepresented and underserved groups to careers in biomedical and behavioral research; (6) "Partnerships and Collaborations" suggests mechanisms to increase PHS involvement in partnerships that improve life sciences education and public science literacy; (7) "People Engaged in Science and Technology" suggests how academic and industry scientists can help PHS increase science literacy and ensure that a pool of well-trained biomedical scientists and technical personnel is available to meet national needs. (ZWH)

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Prologue to Action

Life Sciences Education & Science Literacy

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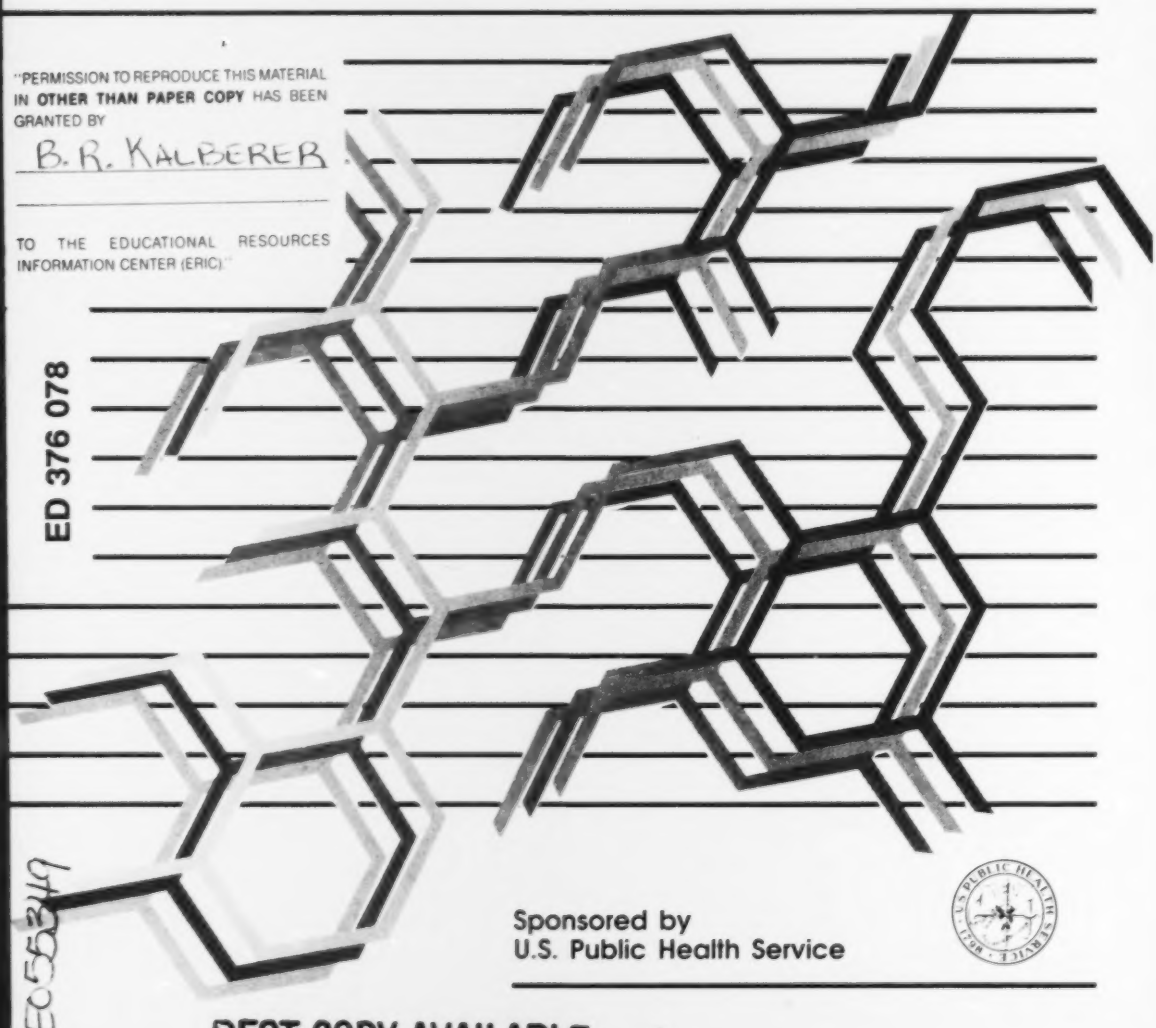

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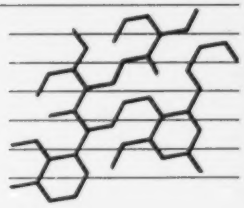

Life Sciences Education and Science Literacy

Columbus, Ohio

March 1992

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Foreword

Science education and public understanding of science, or public science literacy, have become national priorities because of a growing concern that the United States may lose its longstanding position as the international leader in research and development.

One reason for this potential decline in scientific eminence is the dwindling pool of students who are choosing careers in science. If this trend continues, by the year 2000 the number of well-trained research personnel may be inadequate to meet national needs in a number of important fields.

Of equal concern is the low level of science literacy among the American public. General scientific illiteracy compromises America's research capabilities less directly but as certainly as does our failure to prepare new scientists, engineers, and technicians. A public that does not understand the relationship between basic research and improvements in the quality of life is less likely to recognize the importance of support for research in biomedicine and behavior. A public that does not see the relationship of science and technology to society and that lacks skills in decisionmaking and problem solving is hampered in its ability to make informed judgments about the personal and societal implications of science and technology. This point is especially true in the biomedical and behavioral sciences, where research initiatives such as the Human Genome Project and the search for the biologic components of mental illness raise profound questions of ethics and public policy.

Since the 1983 publication of *A Nation at Risk,* which sounded the alarm about the poor state of American education, more than 300 reports have chronicled the serious and systemic deficiencies in our education system in general, and in science and mathematics in particular. Beginning with the National Education Summit in 1989, the problem has received attention at the highest levels of the Federal Government. In 1990, the Federal Coordinating Council for Science, Engineering, and Technology established the Committee on Education and Human Resources (CEHR) to oversee the enhancement and coordination of science education programs among Federal agencies. A CEHR working group named as the areas of science education needing most attention, and therefore its top priorities, improvement of the knowledge and skills of precollege teachers, curriculum development, systemic reform, and student incentives.

The Department of Health and Human Services (HHS) has long been concerned with the depth and quality of the scientific work force—particularly in biomedical and behavioral research—and with public science literacy. HHS Secretary Dr. Louis Sullivan has charged the U.S. Public Health Service (PHS) with developing the Department's response to the national crisis in science education. As a Federal health agency, PHS can bring considerable resources to bear in this effort, but those resources must be applied carefully to ensure maximum effect and to avoid needless duplication of effort.

Against this backdrop of concern for American science education, PHS convened a national conference in June 1991 in Columbus, Ohio. The conference, **Prologue to Action: Life Sciences Education and Science Literacy,** brought together more than 225 teachers, students, school administrators, officials from science museums, research scientists, evaluation specialists, industry leaders, media representatives, and representatives from other Federal agencies to develop recommendations for a coordinated, sustained PHS effort to improve science education and public science literacy in the life sciences.

The conference addressed public awareness, teacher education, curriculum development, student incentives, underrepresented and underserved groups, partnerships and collaborations, and people engaged in science and technology. During the 2-day meeting, participants discussed the issues, reviewed efforts already in place, identified gaps in current programs, and provided a set of recommendations PHS might adopt to improve life sciences education and public science literacy.

The recommendations in this report will be used to develop a strategic plan under the auspices of the PHS Life Sciences Education and Science Literacy Board. The plan will signal the beginning of a comprehensive PHS program to improve life sciences education and science literacy in the United States. Major PHS goals are to foster scientific literacy by increasing understanding of and appreciation for life sciences among the U.S. population and to ensure an adequate supply of life scientists and technical personnel to meet future national needs. Primary target groups are the general public and students in kindergarten through 12th grade. To reach this audience, the agencies will use mission-oriented PHS laboratories, its army of PHS-supported scientists, and methods to involve each agency's constituencies.

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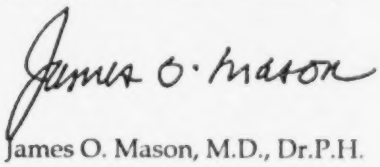
I am grateful to all those inside and outside the Federal Government who devoted time and expertise to make the Columbus meeting a success, and I look forward to their continued involvement as we convert the conference recommendations into concrete programs across the country.



James O. Mason, M.D., Dr.P.H.
Assistant Secretary for Health
Department of Health and Human Services

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Executive Summary

In recommendations springing from the **Prologue to Action: Life Sciences Education and Science Literacy** conference in Ohio, attendees overwhelmingly agreed that PHS should become an aggressive advocate for excellence and equality in life sciences education. PHS, using its influence and resources, should integrate life sciences education and science literacy—particularly for students in kindergarten through 12th grade (K–12) and the general public—into its mission, making them an agency priority.

Most recommendations called for new funds, emphasizing that monies spent on life sciences education should not be taken from other critical agency programs. Attendees urged PHS to leverage existing resources, help disseminate information and materials, stimulate the formation of new partnerships and networks, and make greater use of scientists in curriculum development and teaching. PHS was advised to play a major role in coordinating Federal life sciences education activities. One subcommittee suggested PHS initiate payback loans for those entering the science education field, with debt forgiveness related to service in life sciences education.

Conference participants called for PHS to mobilize its corps of intramural and extramural scientists in the service of life sciences education and literacy by creatively combining the knowledge of scientists with the practical teaching skills of classroom teachers. Scientists should help train science teachers and other educators and help structure learning experiences to ensure that all students have a chance to develop the ability to think and learn on their own. Scientists should help train student teachers at the university level, for instance, and help revise undergraduate science curriculums. They should become local or national speakers, be mentors to local teachers, loan equipment for science class projects in local schools, and get involved in undergraduate and precollege curriculum development.

Conference participants envisioned a system of incentives and awards to encourage this participation and strongly urged that PHS explore every opportunity for working jointly with other Federal agencies and organizations of all kinds.

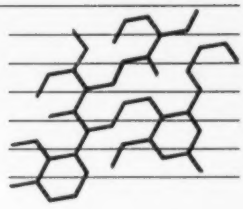
PHS was asked to encourage and support a radical change in science education curriculums by concentrating on human beings in

life sciences studies. PHS should support efforts to help parents learn how to stimulate and sustain their children's interest in science and science careers. PHS was urged to reach out in all public life sciences education efforts to the broadest spectrum of the U.S. population; the heterogeneity of the Nation's population requires that communication efforts mirror the diversity of American culture. In that vein, the participants said, PHS should support career development for underrepresented science teachers and make life sciences education accessible to every student, beginning in the elementary grades. The life sciences could attract gifted individuals of all types. Talented women, individuals with disabilities, members of minority groups, and students from rural schools should view careers in the life sciences as the essence of equal opportunity because the life sciences need their intellects, perspectives, and contributions. To support this effort and related ones, the agency could publicize agency and other health profession resources at regional and local levels that are accessible to teachers and the general public.

Finally, PHS was urged to develop specific programs to implement and support life sciences education goals and to encourage its agencies to promote these activities wholeheartedly.

The following summary of reports from the seven subcommittees includes overviews and discussions of their perspectives, issues, and recommendations for PHS.

Chapter 1.
Public Awareness



Challenge: *Suggest how PHS can improve public understanding of biomedical and behavioral research and its implications for individuals and society.*

The Issues

Although the United States is in the midst of a life sciences revolution, most Americans are ill equipped to understand the fundamental scientific concepts that underlie that revolution or to make sound judgments about the implications of scientific and technological progress. Scientifically literate people should be able to participate in discussions of contemporary scientific issues, apply scientific information in personal decisionmaking, and locate valid scientific information when they need it. These components of scientific literacy in turn require that people be able to understand and evaluate publicly disseminated information on science and technology, distinguish science from pseudoscience, and interpret graphic displays of scientific information. Because the rapid pace and complex nature of advances in the life sciences raise difficult issues of ethics and public policy for the Nation, the public's ability to understand science and technology is critical to the Nation's future.

On the basis of the foregoing criteria, the current level of public science literacy clearly is inadequate to meet the demands of the 21st century, and PHS must therefore reach out to all segments of society with messages appropriate to their needs and educational levels. Recognizing that even the most scientifically knowledgeable people require general information outside their specialty and that the Nation's heterogeneous population requires a diverse, carefully targeted set of initiatives to promote public science literacy, PHS should try to reach people who are now inattentive to the life sciences. It can use traditional channels (electronic and print media) and nontraditional channels (science museums, community or-

ganizations, voluntary health organizations) to reach these diverse audiences.

Popular stereotypes of science and scientists impede the development of science literacy and the recruitment of young people into careers in the life sciences. PHS intramural and extramural scientists can help correct those stereotypes by participating in public awareness programs that convey the human side of scientists and the excitement of research. PHS information campaigns would benefit from collaboration among agencies so that PHS might present a consistent, cohesive message about the life sciences that is compatible with its mission. Interagency collaboration, as well as cooperation with other Federal agencies and nongovernmental groups such as museums and science centers, could help ensure more effective use of the media and greater consistency in the messages that emanate from PHS.

All PHS staff members should feel they have the authority, where appropriate, to help improve public science literacy and to engage in educational activities. The PHS senior staff should support the concept of scientific citizenship for all PHS scientists and related personnel by encouraging and rewarding their participation in various educational programs that seek to improve public understanding of science.

Recommendations

PHS should promote public understanding of biomedical and behavioral research and its applications through the following activities:

1. **Interpret the PHS mission to include life sciences education and public science literacy.** The leadership of PHS should establish this as a priority in each PHS agency and emphasize the need for a comprehensive, sustained effort that helps replace popular stereotypes with realistic impressions of science and scientists.

2. **Develop public education programs that reach the broadest spectrum of the U.S. population by using communication strategies that acknowledge the extraordinary diversity in American culture.** PHS programs should recognize the capabilities and limitations of the various communication

strategies with respect to diverse audiences. Among these channels are broadcast and satellite television and video, radio, newspapers, science museums, community-based organizations, voluntary health organizations, and computer networks and data bases.

3. **Distinguish between advocacy and information in PHS initiatives.** PHS should not engage in direct advocacy, which is properly the function of individuals and private groups participating in the democratic process.

4. **Promote the concept of scientific citizenship among PHS scientists and other staff.** PHS should encourage its intramural staff and extramural grantees to initiate and participate in activities that improve the public understanding of science, and it should reward them for doing so.

5. **Encourage collaboration within PHS agencies and with other organizations involved in public science literacy.** PHS should be prepared to collaborate with the full spectrum of agencies engaged in public science literacy, including other Federal agencies, private sector groups, universities, voluntary health agencies, community-based organizations, museums, and the electronic and print media.

6. **Conduct basic research into the components of public science literacy, formative evaluation of programs in progress, and summative research on the outcomes of all programs.**

Overview and Discussion

Although there is little consensus on the components of scientific literacy, there is agreement that scientific literacy is poor in the United States. A 1988 study, for example, measured scientific literacy in the United States, Luxembourg, the United Kingdom, Denmark, the Netherlands, Canada, France, Italy, Germany, and Ireland. Although none of those countries fared well in the analysis, adult populations in many of them were evaluated as more scientifically literate than the U.S. adult population.

One can view science literacy as a compendium of elements that includes a working knowledge of principles underlying scientific processes and concepts; an awareness of scientific ways of thinking;

and an understanding of the relationship of science, mathematics, and technology to society. It also includes the ability to use scientific information to make informed decisions. One body of research, conducted by Jon Miller, bases its assessment of scientific literacy on (1) mastery of a basic vocabulary of scientific words and concepts sufficient to understand science news as reported in the media; (2) an understanding of the process of science and the difference between scientific reasoning and the research processes associated with other disciplines; and (3) an appreciation of the impact of science and technology on individuals and society. Miller's work, conducted in the United States during the past decade, reveals that only 6.9 percent of the adult population in 1990 could be considered scientifically literate according to his criteria.

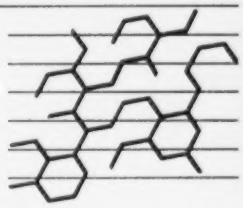
Other research by Miller shows that one can divide the public into three categories with respect to interest in science: roughly 20 percent are attentive to science; another 20 percent are interested, but their attention must be captured; and the remaining 60 percent are uninterested. This does not mean, however, that the 60 percent who are uninterested are incapable of understanding scientific issues. PHS may wish, therefore, to concentrate on capturing the interest of this last group, but any such endeavor must ensure that the public is exposed regularly to the messages PHS wants to promulgate. This consistent exposure must help build a common, public vocabulary for science literacy in areas important to PHS. It may also be necessary to develop programs that convey the same message at different levels of sophistication. In any case, PHS should avoid a quick fix mentality and concentrate instead on a well-planned, cohesive set of messages for the public. Doing so, of course, will require substantial human and fiscal resources.

In constructing its messages for the public, PHS should attempt to convey the value and excitement of science without forcing science on the public or straining credulity by making science look like nothing more than fun. In addition, the PHS message should provide the public with the skills and information to help resist attacks on science by the growing antiscience movement in this country; of course, no one can control whether the diverse groups that comprise the public think science is good. During the discussion at the conference a few participants expressed the belief that in a democracy committed to a free press it is not the Government's responsibility to persuade people one way or another about the merits of science. The PHS objective should be to develop in the public a level of scientific literacy that enables the average person to

understand competing arguments in public policy issues and to distinguish science from pseudoscience or advertising.

A nation that has limited resources to devote to public science literacy could concentrate on upgrading the skills of that 40 percent of the population who already show some interest in science. One could argue, however, that it would be more productive to assign limited resources to improving science education in grades K–12. Students who are well educated about science and technology throughout their formal schooling will carry the requisite knowledge and skills of scientific literacy with them into adulthood. For change to be effected in one generation, all students would have to be exposed to significantly more and better science education in grades K–12, including a requirement that all students take 3 years each of science and mathematics in high school, a requirement already in place in many other nations.

Chapter 2.
Teacher Education



Challenge: *Identify mechanisms through which PHS can help improve the preservice and inservice education of teachers.*

The Issues

Even though many teachers understand well the concepts and processes of science, few mechanisms are available to them for updating their content knowledge or teaching skills regularly. This problem often is exacerbated by outdated or inaccurate curriculum materials. Many teachers who are responsible for teaching science lack the appropriate content knowledge and, equally important, lack an understanding of science as a process of rational inquiry. These deficiencies, which make it difficult to model the processes of science in the classroom, are especially severe among teachers of the elementary grades.

All precollege teachers who have responsibility for science would benefit from a substantive research experience during their undergraduate preparation, and from opportunities to interact regularly with research scientists throughout their teaching careers. Such interactions, which should expose teachers to cutting-edge research and technologies, can improve teachers' skills and increase enthusiasm for teaching. Unfortunately, research scientists who devote time to improving precollege science often are not rewarded or recognized professionally for these important contributions to society and their professions. Furthermore, interactions between research scientists and precollege teachers must be structured carefully if they are to have lasting impact on teaching and learning of precollege science.

In addition to the opportunity to interact with the research community consistently and substantively, inservice teachers should have ready access to highly reliable resources such as books, pamphlets, and videos they can use regularly to update content and teaching skills. The combination of resources and opportunities to

interact with the research community can help alleviate the sense of isolation that haunts many precollege science teachers.

Recommendations

PHS should undertake the following activities in teacher education:

1. **Develop and fund a network of regional centers located in research universities.** The centers should coordinate short- and long-range programs that involve inservice teachers in research and that make educational resources available to teachers throughout the region. Where possible, the regional centers should foster partnerships among scientists, educators, business and industry, museums, zoos, and teachers to broaden the base for opportunities in teacher education. PHS should maintain a national network of the regional centers. The centers, which eventually should spawn smaller satellite centers, could become the hub of activities that include teaching; identifying and sharing of resources and information; equipment loans; and workshops.

In each center's extended community there should be continual communication with schools and a concerted effort to foster networking among teachers and resources. The centers should emphasize the most effective use of existing resources. For example, participating institutions or laboratories should list equipment available for onsite use or loan, and PHS laboratories should serve as sites for teacher education and laboratory internships.

The regional centers should be organized according to the following criteria:

- Applicants can be universities; science-related organizations; or consortia of universities, 4-year colleges, 2-year colleges, museums, private companies, and professional societies. The centers should, where possible, develop cooperative programs with government laboratories.
- Centers must institute mechanisms for ongoing interactions among teachers and between scientists and teachers.
- Centers can be discipline or issue based, and they can be housed in permanent sites or mobile units.

- Centers must be able to provide content expertise, laboratory experiences, and general consulting on science education issues.
- Centers should receive multiyear funding, and renewals should be competitive.

2. **Support the development of programs that involve preservice teachers in substantive research experiences as undergraduates.** Such programs, which are critical for all teachers, are especially lacking in the preparation of elementary school teachers. This level, therefore, should be the highest priority for PHS. Research experiences should promote an understanding of the nature and processes of science and should be substantial enough and last long enough to ensure that the student recognizes inquiry as an essential element of science. Research could culminate in a senior thesis, written under the direction of a life sciences faculty member. Teachers and research mentors should receive fellowship stipends for the required commitments.
3. **Promote and fund increased communication between PHS scientists and precollege teachers through summer institutes, materials development programs, and sabbatical leaves.** PHS should make grants available to research scientists and professors who wish to become mentors to preservice students of science education and to classroom teachers. PHS should model its inservice programs after the growing number of exciting programs that could be adapted for use nationwide. The PHS administration should communicate to its 75,000 staff members and grantees the importance of their involvement in precollege science and should provide concrete help for PHS scientists who wish to contribute to the improvement of science education. PHS should establish incentives for grantees and staff to influence science education at the local level.
4. **Encourage and support tours of PHS research facilities to familiarize preservice and inservice teachers with the technologies used in the life sciences, especially telecommunications, data base management, and computer applications.**
5. **Serve as a model for other scientific organizations.** PHS should encourage scientific societies to develop education committees and to devote some national and local conferences to updating information and resources for teachers. PHS already

has initiated one such model with the Society for Neuroscience, which hosts teachers for 1 day before its national conference.

6. **Establish a PHS career development award for precollege science teachers and develop new fellowships to allow teachers to take sabbatical leaves for coursework or laboratory experience.**

7. **Support development of science courses for kindergarten through college that integrate the sciences; that are investigative, experiential, and issue oriented; that involve students in collaborative study; and that involve appropriate technology.** Such courses will help retain qualified teachers.

8. **Support community-based recruitment of excellent teachers through efforts such as those that have been used to recruit African-American students through local churches.** PHS should make scholarships available to minority students who pursue studies in life sciences education and should identify and publicize minority and female role models in science to encourage such students to choose science careers.

Overview and Discussion

It is clear that science education would benefit from programs that combine the content knowledge of research scientists with the practical teaching skills of classroom teachers. PHS should use its resources and influence to establish and sustain such programs. The research community must work with teachers to identify central concepts and content and to ensure that all students are exposed to a view of science that accurately represents the scientific enterprise.

PHS has the human and fiscal resources to link the biomedical and behavioral research community with life sciences education at every level. For example, PHS could foster relationships between its grantees and teachers in the local community. A new service could help match local teachers and local scientists by circulating among local teacher organizations a list of grantees and their areas of expertise so teachers can access various kinds of help. Conversely, PHS can help make lists of life sciences teachers available to professional societies so that teachers could be matched with scientists who want to be involved at the local level.

Exchanging lists, however, is not sufficient to sustain changes in teaching and learning. PHS should work with its scientists to help them initiate contact with teachers and to show the scientists how to help develop classroom materials or how to be most effective in a precollege classroom. The success of local programs would increase with the level of guidance.

PHS intramural and extramural research scientists and staff can contribute to the improvement of science education in a number of ways: by participating in inservice institutes for teachers; identifying inaccurate, outdated, or unnecessary information in textbooks; promoting change in the community; being a mentor for a teacher; teaching teachers (preservice and inservice); allowing a laboratory to be a field trip site; lending or donating equipment; and helping develop materials through teacher-scientist partnerships.

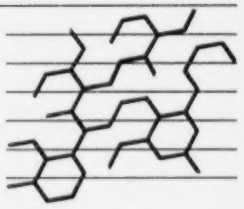
Strategies for teachers include PHS-supported sabbatical leaves; workshops to improve skills; mobile laboratory teaching units; university- and college-based teachers' institutes; community adopt-a-school programs; participation in programs at national and local conventions of teachers' organizations; grant options that ask new grant applicants to participate in science education programs; and help from societies of professional administrators, especially societies whose memberships include school administrators.

PHS grant applications could request information about the ways applicants or their institutions are helping to improve or might improve science education in their communities. Scientists can contribute individually, or the grantee institution can develop a plan for enhancing public literacy in the life sciences. PHS must make it easy for institutions to comply by minimizing paperwork and by establishing flexible guidelines that encourage individuals and institutions to develop creative programs that respond to unique local needs and resources.

Another way to encourage the involvement of PHS scientists in science education is to make funds available to institutions that participate in outreach efforts in life sciences education. Many institutions and individuals devote time to developing strategies for outreach programs, as evidenced by the number of applicants for the Science Education Partnership Awards (SEPA) sponsored by the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) and the National Institutes of Health (NIH). PHS could support networks that bring together successful and unsuccessful applicants to exchange ideas.

Most important, PHS should take the lead in promoting change by demanding and supporting excellence in life sciences education and science literacy at all levels.

Chapter 3.
Curriculum Development



Challenge: *Suggest how PHS can help develop and implement science curriculums that will ensure there is a pool of well-prepared biomedical and behavioral scientists, and identify how PHS can contribute to general scientific literacy.*

The Issues

Current reports on the status of science education confirm that the traditional life sciences curriculum must change radically if precollege science education and public science literacy in the life sciences are to be improved. New curriculums in the life sciences, at all grades, should be human oriented, concentrating on concepts and skills that will help students live healthy lives and sustain a healthy planet in a rapidly changing world influenced profoundly by science and technology. In the words of distinguished science educator Paul DeHart Hurd, "Students should not grow up as strangers in their own culture." The proposed human orientation is clearly consistent with the mission of PHS and should focus PHS activities in science education.

The life sciences curriculum must demonstrate to students that contemporary biology is evolving into a complex, multidisciplinary field influenced increasingly by advanced technology, both in basic research and in its applications to human health and well-being. Especially relevant examples include genetic molecular biology, behavior, and ecology, which provide excellent opportunities for students to consider the personal and societal implications of life sciences. The curriculum should provide students with the skills required to make informed decisions about the science and technology that affects them and society so profoundly, and it should emphasize science as a process of rational inquiry to help students distinguish scientific thinking from that which is nonscientific or antiscientific.

This view of life sciences should begin at the earliest grade levels to take advantage of children's natural curiosity about the world, and it should be the focus for the life sciences curriculum throughout the precollege years. The life sciences curriculum should engage and retain the interests of all students by providing educational experiences that focus on human biology and involve students in intellectually sound, hands-on experiences. By helping engage and retain the interests of all students, PHS can help ensure that a steady stream of potential scientists will move through the educational pipeline with sound exposures to science.

The rapidly changing nature of biology and the proposed human orientation to the life sciences curriculum will require classrooms that are well equipped with appropriate scientific equipment and supplies and with current technologies such as telecommunications, computer graphics, and simulation software. In addition, the school schedule should acknowledge the importance of laboratory and field investigations in science and should provide time and resources as required.

Teachers must find effective ways to stay abreast of the latest research in the life sciences and must have access to materials that will help improve their teaching. Because classroom time is limited, PHS programs and partnerships should be planned so that teachers can use them effectively and efficiently.

Any PHS involvement in the development of new curriculums must (1) begin with a comprehensive review of past reforms, (2) avoid repeating past mistakes, (3) base current reforms on school-effectiveness research, and (4) integrate all elements of reform: curriculum, assessment, and teacher preparation.

Recommendations

PHS should undertake the following activities in curriculum development:

1. **Develop and fund a national advisory council for education composed of working subcommittees that include a curriculum group and representatives from teacher organizations, scientific societies, and the private and public sectors.** PHS should not create a new life sciences curriculum, but it should strongly encourage and support programs that are

human orientated in the life sciences curriculum and that emphasize hands-on, inquiry-oriented learning.

2. **Establish an office of educational resources to coordinate and disseminate resources such as curricular materials from Federal agencies, listings of videotapes or speakers, locations of U.S. laboratories available for tours, and scientists available to be mentors and speakers.** PHS should continue to develop, produce, and distribute material pertinent to education in life sciences and health, and it should develop and provide publications about careers in those fields. PHS also should establish a clearinghouse—or work with the Department of Education's planned clearinghouse in science and mathematics—to distribute materials and information about programs in the life sciences and to encourage recruitment and retention of those in underrepresented groups. The clearinghouse should disseminate summaries of current, significant PHS-supported research that are written at levels appropriate for the nonspecialist.

3. **Initiate and support educational partnerships that allow scientists to participate in the improvement of curriculums in the life sciences.** Chapters 2 and 6 include additional recommendations about the nature of partnerships among educators, scientists, and the community at large.

4. **Establish a minigrant program to support teacher attendance at national and regional conventions such as those held by the National Association of Biology Teachers and the National Science Teachers Association.** The program should provide grants of $500 to $600 to support teachers who wish to make presentations related to life sciences education. In addition, PHS should encourage its own personnel to make presentations at national and State teachers conventions.

5. **Add a line item to the PHS budget to provide major funding for a PHS initiative in life sciences education.** These funds should be supplemental and should not be transferred from the existing, inadequate PHS budget for scientific research.

6. **Focus special attention on elementary education.** The early years are decisive for forming beliefs and attitudes about science, and efforts directed to elementary students will have multiplier effects in the pipeline that leads to careers in science. Furthermore, it is critical to reach underserved and under-

represented groups early so that they are not shut out of the pipeline.

Overview and Discussion

Although several hundred books about the changing state of American society, economics, and science appeared during the late 1960's and the 1970's, only a few—among them Charles Silberman's *Crisis in the Classroom,* and Alvin Toffler's *Future Shock*—addressed the educational implications of those changes. The essential message was that the future would bring vast changes and that teaching would have to adapt to prepare students for a changed world. Unfortunately, those predictions did not stimulate wholesale reform of American education.

The future predicted in the 1960's is here, but substantive educational reform has yet to occur. In 1983 the Department of Education's Commission on Excellence produced *A Nation at Risk: Imperatives for Education Reform,* which shocked schools, government officials, politicians, and the public into action. The widespread reaction to the publication has not resulted in widespread reform, however, partly because assigning blame for our problems has taken precedence over implementing sound reform efforts.

In the 1990's, however, President Bush has charged the United States with being first in the world in science and mathematics by the year 2000 and has encouraged Americans to work together to develop new approaches to education. Many educators believe the creation of entirely new approaches is appropriate, given the anachronistic nature of the current system.

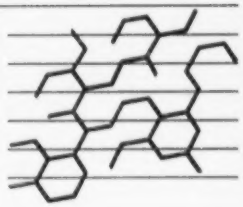
Although the life sciences curriculum certainly would benefit from a "reinvention," some researchers who study educational change hold that curriculum reform often is an illusion because school systems are constructed as loosely coupled agencies that make nationwide changes in curriculum difficult. Furthermore, because there is limited power at the top of the educational system, the mechanisms on which industry relies to effect change from the top down do not work in the school culture.

Research does show, however, that curriculum reform is possible when all components of the system are involved and supportive. Reform also is more likely when excitement is generated in the

process; charismatic teachers and principals are as important as new curriculums. Those involved in curriculum reform must remember that change tends to be incremental; it is a process rather than an event. One must support change throughout the process and must also acknowledge the influence of the curriculum that is being replaced. No new curriculum is inserted into a vacuum; administrators, teachers, students, and parents hold prior assumptions about what a curriculum is supposed to look like and accomplish.

Assessment is an important and controversial part of any curriculum; indeed, it often drives the curriculum itself. Although assessment can provide powerful incentives for staff development as teachers prepare students for mandated testing, poor tests—for example, those that focus on simple recognition of vocabulary—also can reinforce poor curriculum. One must view curriculum and assessment as a complete package and choose assessment strategies that are consistent with the curriculum objectives. There is considerable research under way on new assessment strategies that are more congruent with the objectives of inquiry-oriented curriculum, for example, open-ended questions, student portfolios, and drawings, which can help assess learning achieved by students who are not proficient in English.

Chapter 4.
Student Incentives



Challenge: *Suggest how PHS can attract students to and retain their interest in the study of life sciences.*

The Issues

The public image of science can be improved to better serve the Nation. Too many people think science is difficult, mystifying, and inaccessible; that its uses are baffling and have nothing to do with daily life; and that it is too complex for "ordinary" people, particularly children. PHS must help revamp this image to fulfill its goals of improving precollege education and creating a scientifically literate public.

Parents and other adults can help disabuse children of common misconceptions about science, particularly if they become more involved in the educational process. Adults can be helped to gain knowledge and thus become more confident about encouraging children to participate in the life sciences or pursue life sciences careers. Adults also can help children understand that science is critical to the education of an informed citizen in a technologically advanced society. Further, the content and methods of science education programs can be better targeted to the developmental levels of students for whom they are intended.

Since demographic data indicate that the Nation's scientific and technological expertise must be drawn increasingly from groups that are traditionally underrepresented in the sciences, science education and literacy programs must be made more sensitive to distinctions based on sex, race, class, culture, and community (see ch. 5). It is important, therefore, to provide role models and mentors for elementary and middle-school students. These mentors can be high school and college students (undergraduate and graduate) or adults involved in some aspect of the life sciences. Mentorship programs must attend to cultural diversity, involve individuals with

disabilities, and create opportunities for children to help one another through cooperative learning and tutoring across age groups.

Programs that offer hands-on science will most effectively engage and retain students in the life sciences. Such programs should involve children directly in exploring the physical and biologic world and have cooperative learning as a central approach. Parents and other adults must be involved, and they may need to be taught how to provide positive messages that encourage children to participate in the life sciences. They can help promote the study of science in all settings that children encounter, particularly those that reach children in underserved and underrepresented groups.

Recommendations

PHS should provide student incentives through the following mechanisms:

1. **Support a national parent-education campaign aimed at "things parents can do" to stimulate and sustain their children's interest in science and in careers that require a science background.** This proposed joint effort among Federal agencies must reflect diverse languages, households, and family composition, and it should use the media that are most effective in reaching different communities and cultures. Two interventions must precede the proposed campaign. The first is a review of extant materials to establish availability, quality, and appropriateness for age, sex, culture, and language. The second is a commitment to fill the gaps revealed by the review and to initiate at the agency level, or through competitive grants and contracts, the development of materials where gaps exist.
2. **Support development, production, and dissemination of life sciences education programs that directly involve children in exploring the physical and biologic world** (see ch. 3). These programs should use cooperative learning as a central approach for students and should encourage parent involvement in children's learning. The programs should encourage the learning of science in diverse environments, particularly those accessible to underserved groups, and should be sensitive to differences based on sex, race, class, culture, and community. The programs' content and methods must be developmentally

appropriate and should focus on health issues that are important to students and their parents. The instructional setting should be rich in materials and equipment, including things that children can borrow and take home.

3. **Adapt and develop materials to encourage and educate children and adults about careers in the life sciences, and help parents become more effective career counselors for their children.** PHS should support and coordinate a nationwide information-dissemination system or a national career-awareness program in the life sciences. These efforts should employ television, radio, and print and should provide access to materials such as short videotapes on careers in the life sciences that include role models representing various ethnic groups.

4. **Offer science awards that are available to and within reach of all children.** These awards should recognize children who are high achievers in the life sciences as well as students who gradually build their scientific knowledge, skills, and motivation to pursue careers in the life sciences. The awards also should recognize individual and group effort. Awards for older children might include annual, accomplishment-based, national science awards and a special award for high school seniors such as a presidential science award based on criteria that include a minimum of 3 years of coursework in the sciences.

5. **Support science education efforts that are multilingual and multicultural and that use hands-on science as a way to build a common language of learning.**

6. **Extend the NIH Minority High School Student Research Apprentice Program.** Consideration should be given to changing the focus of this program to include industrial laboratories, museums, hospitals, health organizations, forestry departments, government agencies, and science museums so that students can learn firsthand about a variety of careers in the life sciences.

7. **Support the formation of national science clubs in school and community settings and the formation of a national science honor society.**

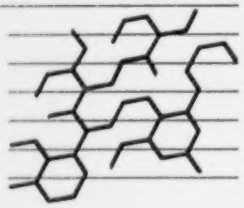
8. **Develop a nationwide system of "science education agents."** This long-term developmental strategy will require careful planning and acquisition of new resources. The training of science education agents must include academic preparation in the sciences, and candidates must be able to coordinate resources that link the classroom teacher to new teaching technologies, scientific information, and the scientific community. Potential locations for the agents include universities; area health education centers; State departments of education, health, and the environment; and county and city governments. The Department of Agriculture's Agricultural Extension Program could serve as a model for the proposed program.

Overview and Discussion

A number of barriers between schools and parents and between communities and industry impede the ability of teachers to reach students with positive messages about the life sciences. Partnerships that link these institutions and individuals can help overcome those barriers and can lead to the development of incentives that attract students to science, as proposed in the recommendations. Among the least exploited mechanisms for attracting students to science are those grouped under the term "informal education," including afterschool, Saturday, and summer activities; museum-based programs; media programs such as "3-2-1 Contact" and "Reading Rainbow"; and science news magazines and newsletters for children.

If young people have opportunities to make decisions about how they learn and become involved in meaningful community action projects related to health and the life sciences, they may gravitate increasingly toward science-oriented careers and improve their ability to take their rightful places as scientifically literate citizens of the next century.

Chapter 5. Underrepresented and Underserved Groups



Challenge: *Suggest mechanisms that help PHS attract and retain underrepresented and underserved groups to careers in biomedical and behavioral research.*

The Issues

The Bureau of Labor Statistics predicts that the future talent pool for scientists and engineers will be composed predominantly of women, racial or ethnic minorities, and individuals with disabilities[1]—those groups the Nation traditionally has failed to attract to careers in science, mathematics, and engineering. Solving the problem of reaching underrepresented and underserved groups will require a comprehensive approach that will involve students, parents, teachers, communities, scientists, and government.

Many who choose careers in science are influenced by teachers, family members, or friends, but that nurturing environment often does not exist for underserved and underrepresented youth. PHS can help overcome this deficiency through programs that show underrepresented and underserved groups that science is accessible, important, interesting, and a viable career option. Although the problems are complex, there are some obvious strategies that can be employed to reduce the social and cultural deterrents that prevent women, members of minority groups, and individuals with disabilities from developing an early interest in the life sciences and maintaining a general interest in science and mathematics throughout the later years.

[1] *The issues of underrepresented groups differ from those that affect underserved groups. For example, women and minorities are underserved because their health issues have not been a focus of research and because women and minorities have not been included as research subjects. They are underrepresented as students and researchers, as well. Such groups include women, African-Americans and Hispanic-Americans, Native Americans, some Asian and Pacific Islander ethnic groups, people with disabilities, and those in rural areas.*

The problems often begin early, with teachers who have low expectations of members of minority groups and women and communicate messages that promote low self-esteem. These problems are reinforced by barriers of language and culture. Such expectations often become self-fulfilling prophecies as the school, the teachers, and the curriculum reinforce misconceptions that science is for the elite, that science is too hard, and that learning science will alienate students from families, friends, and culture. These misconceptions are reinforced by an emphasis on competition, rather than cooperation, in learning science.

In addition, many underserved groups attend schools that do not have the teachers, facilities, or resources to develop or stimulate interest in the life sciences. There is an across-the-board lack of classroom role models for underserved and underrepresented groups, including women and individuals with disabilities. Society places too little value on teaching, making it difficult to recruit and retain teachers skilled in the life sciences, and new teachers often do not view themselves as part of the scientific community. Even experienced science teachers may be uncomfortable with subject matter in the life sciences, especially where laboratory investigations are concerned, because they lack hands-on training.

The traditional life sciences curriculum exacerbates the problem because it seldom includes topics relevant to the daily lives of underrepresented and underserved students, and there is little supplemental information about contributions to the life sciences by those groups. PHS can help alleviate this problem by involving its scientists in the development of curriculums that demonstrate the relevance of life sciences to the lives of students, that include role models from underrepresented and underserved groups, and that encourage such groups to consider careers in the sciences.

Such efforts to improve curriculum need reinforcement by media messages that present scientists in a more positive manner, especially to underrepresented and underserved children and their parents. These messages should strive to create an atmosphere in which excelling in science and mathematics is considered as important as excelling in athletic or other nonacademic endeavors.

The ability to provide underrepresented and underserved groups with sound, consistent messages about science also is impaired by the lack of resource directories, data bases, meetings, and opportunities for national exchange of information about underrepresented and underserved groups in the life sciences. PHS can

help alleviate this problem by supporting the development of information networks that offer teachers, students, parents, and the community comprehensive information about educational opportunities in the life sciences for all students, as well as information on successful, established programs that help recruit and retain life sciences students from underrepresented and underserved groups.

Recommendations

PHS should undertake the following activities to attract underrepresented and underserved groups to careers in biomedical and behavioral research and retain them:

1. **Collaborate with agencies such as the Department of Education and the National Science Foundation to promote and support programs that make life sciences accessible to all the Nation's citizens.** PHS should work with these agencies to develop culturally relevant curriculums that include contributions of those in underrepresented groups. Research scientists must be involved in developing curriculums to ensure scientific integrity.
2. **Support career development for underrepresented teachers and teachers who serve large populations of underrepresented students.**
3. **Support courses that help K–12 teachers use teaching strategies that promote equity in the classroom.** Skills such as cooperative learning, for example, allow all students to participate and achieve in the life sciences. Teacher-education programs also should help teachers be advocates for careers in the life sciences and involve underserved and underrepresented students in exploring career options. PHS also should support teacher training in curriculums that integrate the life sciences and minimize student tracking, and it should support teaching mentorships for postsecondary life sciences faculty who teach prospective K–12 teachers.
4. **Support underrepresented, nontraditional reentry students who want to pursue careers in the life sciences.**
5. **Adapt the Minority High School Student Research Apprentice Program to the elementary level and adapt the Minority**

Access to Research Careers (MARC) Program to the K–12 level.

6. **Develop a "Life Sciences for Life" media campaign that uses culture- and gender-sensitive posters, videotapes, public service announcements, and television programming.** The campaign should help demystify life sciences for the audience and should use role models such as PHS scientists, or athletes in messages about sports medicine.

7. **Conduct national meetings for directors of exemplary life sciences education programs that serve underserved and underrepresented groups.** These meetings will provide a forum in which directors can share experiences and build partnerships.

8. **Support research to determine the attitudes of women and minorities toward the life sciences.** The research should generate data about the impact of cultural and ethnic backgrounds, gender, age, and language.

9. **Attract members of underserved and underrepresented groups to life sciences research by supporting biomedical research in areas that affect those groups.** PHS also should increase representation from underserved and underrepresented groups on review panels and in policymaking positions.

10. **Develop and maintain a detailed, computer-accessible list of life sciences education programs that promote life sciences careers for those in underserved and underrepresented groups.** The material should be distributed to schools, community groups, health service agencies, higher education institutions, and related public and private agencies, and it should include information about state-of-the-art life sciences curriculums for schools, teachers, school districts, and community organizations.

11. **Establish programs that give teachers experience in life sciences laboratories or clinics.** Teachers who represent underserved or underrepresented groups or who teach such students should have priority in these programs.

Overview and Discussion

Factors that affect the participation of members of minority groups, women, and individuals with disabilities in science and mathematics include the popular image of science, the expectations of teachers, parental encouragement, and participation in extracurricular activities.

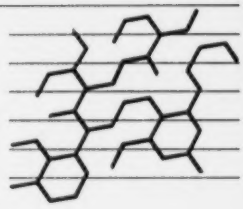
Although many students and adults perceive life sciences as a difficult course of study that requires extraordinary abilities, this misperception is even more pronounced among underrepresented and underserved groups. The stereotype is that science is a male domain populated predominantly by white men living socially and intellectually solitary lives. It is little wonder this image is unappealing to students who do not fit this mold. In reality, the life sciences often are a collaborative effort among many people of both sexes and of diverse abilities, backgrounds, and ethnic groups.

Even if students' beliefs about the life sciences do not fit the reality, those misperceptions have a powerful impact on their decisions to participate in life sciences classes and pursue related careers. There is a need, therefore, to address the discrepancy between students' perceptions and science as it is actually conducted.

Programs that encourage the full participation of students from underrepresented and underserved groups should

- intervene as early as possible in the educational continuum;
- consist of collaborative efforts among teachers and scientists, business and industry, and the community;
- use a hands-on approach to teaching; and
- involve parents.

Chapter 6.
Partnerships and Collaborations



Challenge: *Suggest mechanisms to increase PHS involvement in partnerships that improve life sciences education and public science literacy.*

The Issues

Although problems in American science education are disturbing and serious, there is an unprecedented commitment now to make things better. President Bush, executive officers of major corporations, university chancellors and presidents, State Governors, and community leaders have made strong statements about the need to improve education in mathematics, science, and technology. These pronouncements underscore the point that, for the first time, improving education is seen as a collective responsibility.

Education is unlikely to improve unless many of the Nation's key institutions shift resources toward collaborative efforts to improve the quality of education. PHS must therefore encourage alliances that involve scientists, engineers, and other technically trained professionals from universities, industry, military services, museums, and government agencies. There is, however, insufficient funding to encourage development of science education partnerships. If the PHS science education initiative is to succeed, PHS must support it with sufficient staff and material resources and with adequate funding to support nationwide the robust development of alliances, collaborations, and partnerships. Further, because the scientific community's enthusiastic cooperation is critical to the success of PHS science education efforts, funding for science education and literacy and public science literacy must not conflict with funding for research. PHS should request increased funding for both activities—including line item authority for science education—and leverage its resources as effectively as possible. This strategy calls for PHS line item funding to promote life sciences education and science

literacy through alliances, partnerships, and coalitions at the local, regional, and national levels.

Successful partnerships should enhance access of educators and the public to resources of the health care, nutrition, biotechnology, and pharmaceutical communities and improve the public's understanding of the life sciences to foster healthy behavior and informed health care decisions. Such collaborations require interactions among many disciplines and should strive to show special interest groups that their concerns and objectives have common elements the partnerships can effectively address.

Many cultural and systemic disincentives inhibit the participation of PHS scientists in precollege, college, and public education in the life sciences. To encourage such participation by intramural scientists, PHS must modify obstructive personnel and operating procedures. To encourage participation by grantees and extramural scientists, PHS should create incentives that recognize and reward these activities and encourage grantee institutions to do the same. Such incentives include support for innovative projects proposed by competent scientists who are without current research grant support.

Alliances that promote life sciences education must reach out more effectively to underserved populations, including students and teachers in rural areas, students with disabilities, members of minority groups, and other underrepresented groups. Governing boards of alliances should include increased representation from minority groups.

Recommendations

PHS should support partnerships and collaborations through the following mechanisms:

1. **Create a mission statement for PHS and its agencies that includes precollege life sciences and public science literacy as priorities.** It is important that PHS establish as a priority a long-term funding policy to support life sciences education. Appropriate funding mechanisms include those similar to the mechanism developed for the Biomedical Research Support Grant Program to encourage creative and innovative life sciences education projects at institutions that are PHS grant

recipients. Such a program might be funded by requiring institutions to devote a percentage of their overhead charges to the program. Institutions agreeing to do so would be allowed to increase their allowable overhead by some maximum value.

2. **Promote life sciences education and science literacy through alliances, partnerships, and coalitions at the local, regional, and national levels.** PHS should offer these groups annotated lists of resources that are available to teachers and the general public at the regional and local levels and should work with coalitions to fund and support regional conferences to promote and develop additional alliances. The educational focus of PHS collaborations should be human health, and PHS should engage the health care, nutrition, neuroscience, biotechnology, and pharmaceutical communities in collaborations that take advantage of the resources and prestige of PHS and its agencies.

3. **Seek authorization and new funding from Congress for an expanded role in life sciences education.**

4. **Expand existing programs that promote life sciences education through competitive and noncompetitive mechanisms and continue support for successful partnership programs.** For example, PHS should develop a mechanism to encourage and nurture Science Education Partnership Awards[1] among groups that currently do not receive grant funding.

5. **Expand the functional responsibility of PHS national and regional offices to include K–12 life sciences education and public science literacy.** In particular, PHS should create a permanent, high-level PHS position to coordinate its efforts in this area.

6. **Continue to work with the Federal Coordinating Council for Science, Engineering, and Technology to coordinate science education activities, adopting elements of successful models at other agencies.**

7. **Establish a fellowship or scholarship program to support "bridging" people who are familiar with life sciences and**

[1] *The ADAMHA–NIH Science Education Partnership Award (SEPA) supports model programs that link scientists and educators in enhancing public understanding of science, particularly that related to addictive disorders and mental illness, and in encouraging young people to enter careers in these areas. SEPA is designed to involve scientists in the development of science education programs for K–12 students and the general public.*

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education and who can serve as coordinators of outreach programs.

8. **Establish nonmonetary rewards that encourage scientists to become involved in life sciences education.** Examples include letters of appreciation from PHS agency heads to the individual's superior for inclusion in personnel files, prestigious competitive sources of funding for innovative programs, and riders for graduate training grants to promote outreach education programs that are to be delivered by graduate students or principal investigators.
9. **Establish graduate training programs that offer outreach education programs as a service activity for students in research or science education.**

Overview and Discussion

Insufficient funding is the most important barrier to the PHS focus on life sciences education and science literacy. Adequate allocation of PHS funds will be the most important factor in ensuring the success of this important initiative. Another barrier is the failure to find enough biomedical and behavioral scientists to participate in partnership activities. This deficiency is due partly to a previous emphasis of the partnerships on the physical sciences and partly to the perception of biologists and behavioral scientists that participation in precollege and public life sciences education is unimportant. The lack of incentives for involvement by scientists also impedes the development of partnerships. In fact, the current system rewards only research output; PHS clearly can help change this situation.

Although some life scientists may become interested independently in educational activities, PHS can foster the involvement of a larger group and create an environment in which precollege educational activities become an expected professional activity of research scientists.

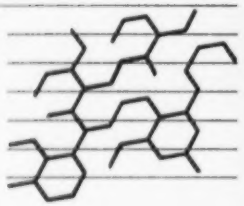
PHS support also can help overcome the historical lack of attention to underserved groups in collaborative efforts. Because of this inattention, women and members of minority groups typically do not sit on organizing boards of most partnerships, and minority and rural schools have received insufficient attention from these groups. It is essential in forming and supporting partnerships that

PHS help ensure that all segments of the population can participate in the work of science and that students in all locations can be served by PHS-supported partnerships.

Another critical barrier to the formation of partnerships is the lack of accessible data about the initiation, organization, and maintenance of such groups and sources of participants. PHS can help by establishing data bases, clearinghouses, and other distribution mechanisms. Doing so would promote the development of new partnerships and allow biomedical and behavioral scientists to identify successful models, speeding up the process of incorporating the life sciences into partnership activities.

The stage is set for PHS to signal its own commitment to improving life sciences education at the elementary and secondary levels, and the Secretary of HHS has recognized the need. PHS has an extraordinary array of human and other resources in the life sciences. It is uniquely positioned—working with other agencies—to enter into collaborative arrangements with local, regional, and national groups to influence the education of young people in an area—human health—that is of unquestioned importance. No other agency can do the job as well.

Chapter 7.
People Engaged in Science and Technology



Challenge: *Suggest how academic and industry scientists can help PHS increase science literacy and ensure that a pool of well-trained biomedical scientists and technical personnel is available to meet national needs.*

The Issues

The PHS focus on health can help make life sciences education relevant to everyone, and the large number of PHS intramural and extramural scientists available for partnerships provides significant potential for fostering communication between intramural scientists and the public. These strengths will not be adequately employed, however, without an organizational mandate to enhance life sciences education.

Furthermore, funds for science education should not compete with research funds. The effort to expand the biomedical research enterprise and bring the benefits of new scientific advances arising out of biotechnology and biomedical sciences deserves the highest priority. Its success, however, rests entirely on the health of the biomedical research enterprise. The members of the **Prologue to Action** Task Force, as well as the overwhelming majority of those present at the Ohio meeting, expressed deep concern that this research effort not be compromised to provide resources to educational programs. The research enterprise is in danger of collapse if more funding is not forthcoming in its behalf, and the morale of those who have dedicated their lives to biomedical research is declining at an alarming rate. Any effort to undermine research at this critical time will destroy the cooperative, positive interactions between research and education that are the essence of any PHS effort to improve science education in the United States.

We urge in the strongest terms that new resources be identified for the important effort to establish and support any PHS-sponsored educational programs. It is clear that a major resource of willing and skilled scientists is awaiting leadership from PHS in educational activities. For these activities to succeed, however, there must be active recognition of the crucial interaction between a well-supported research enterprise and any educational efforts involving PHS-supported scientists. PHS has a rich tradition of success in supporting a broad biomedical research program that has brought remarkable progress in understanding of the human body, genetics, and the pathology of disease. Cures for diseases are now available and information about humans is ripe for use as exciting teaching material to which everyone in America can relate. We must not endanger the potential for using this resource by further limiting its support.

Recommendations

PHS should undertake the following activities to involve people engaged in science and technology in partnerships:

1. **Emphasize life sciences education as part of the PHS mission by establishing an office of science education and science education policy directly under the Assistant Secretary for Health to guide PHS education efforts and coordinate such activities with outside agencies, institutions, and industry.**

2. **Establish partnership grants for professional societies, industry, universities, colleges, and other institutions and community groups.** These grants should provide stable funding and include regular institutional overhead costs and postdevelopment publication of materials. The grant program should give priority to programs that encourage grassroots partnerships and should establish mechanisms to help universities, colleges, and schools acquire laboratory equipment. In addition, funding for the development of partnerships should be staged to cover the costs of various phases of program development.

3. **Provide grants to scientists who want to help develop innovative education programs for rigorous research into education-**

al methods. The grants must be a source of stable funding and provide for regular institutional overhead costs.

4. **Provide incentives in the form of supplemental funding for those who include science education activities in extramural grant applications.** Supplemental funding should be evaluated separately from research funding.
5. **Establish regional industry nodes to develop training programs in science education.** These nodes should focus on the interests of specific industries whose resources can be applied to improving science education.
6. **Expand the Minority Biomedical Research Support Program, the Minority Access to Research Careers (MARC) Program, and the Minority Institution Research Development Program, explicitly including undergraduate students who intend to teach K–12 science or mathematics.**
7. **Implement payback loans for those entering the field of science education, and provide debt forgiveness related to service in science education.**

Overview and Discussion

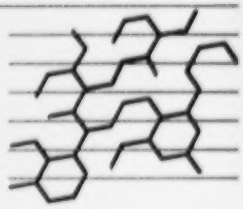
The need for increased collaboration among educators and scientists results largely from the increasing volume of scientific information. As the amount of information expands and the number of science subspecialties increases, the ability to disseminate information about scientific advances grows correspondingly difficult. Not only is it difficult to communicate from the research end of the science information continuum to the end user, but users' needs are not being communicated consistently to researchers. As a result, scientists, science educators, and the public are becoming increasingly alienated. This communication breakdown has serious implications for teaching and using scientific information in the United States.

One potential solution is one-on-one mentoring, whereby skills and knowledge are passed from one individual to another. A second strategy is to develop a large-scale system that addresses the needs of target populations. Mentoring programs are easier to implement and more personalized, but relatively few mentors are available and the transfer of knowledge does not always work in practice.

Development of a system, on the other hand, ensures a consistent approach and the ability to reach a larger proportion of the population. The drawbacks of this strategy include larger initial costs and the inability of a system to adapt readily to individual needs. Despite the drawbacks, either strategy could help establish critical communication links between scientists and students, scientists and teachers, and scientists and the public.

Recommendations for areas of intersection between scientists and science educators were identified during the 1991 National Life Science Education Summit (the Wingspread conference) in Racine, Wisconsin. These recommendations included university sponsorship of internships and workshops for high school biology teachers; development of instructional and curricular materials by teams of teachers and scientists; involvement of professional societies to improve the precollege teaching environment; interaction among scientists' and teachers' organizations; regular interactive sessions for merging the competencies of teachers and scholars; rewards for science education efforts; and methods for fostering interaction among scientists and minorities and women. These approaches are worthy of further investigation for potential application by PHS.

Appendix A.
Summary of Recommendations



Public Awareness

PHS should promote public understanding of biomedical and behavioral research and its applications through the following activities:

1. Interpret the PHS mission to include life sciences education and public science literacy.
2. Develop public education programs that reach the broadest spectrum of the U.S. population by using communication strategies that acknowledge the extraordinary diversity in American culture.
3. Distinguish between advocacy and information in PHS initiatives.
4. Promote the concept of scientific citizenship among PHS scientists and other staff.
5. Encourage collaboration within PHS agencies and with other organizations involved in public science literacy.
6. Conduct basic research into the components of public science literacy, formative evaluation of programs in progress, and summative research on the outcomes of all programs.

Teacher Education

PHS should undertake the following activities in teacher education:

1. Develop and fund a network of regional centers that are located in research universities; that coordinate short- and long-range programs that involve inservice teachers in research; and that make educational resources available to teachers throughout the region.
2. Support the development of programs that involve preservice teachers in substantive research experiences as undergraduates.

3. Promote and fund increased communication between PHS scientists and precollege teachers through summer institutes, materials-development programs, and sabbatical leaves.
4. Encourage and support tours of PHS research facilities to familiarize preservice and inservice teachers with the technologies used in the life sciences, especially telecommunications, data base management, and computer applications.
5. Serve as a model for other scientific organizations, encouraging scientific societies to develop education committees and to devote some national and local conferences to updating information and resources for teachers.
6. Establish a PHS career development award for precollege science teachers and develop new fellowships to allow teachers to take sabbatical leaves for coursework or laboratory experience.
7. Support development of science courses for kindergarten through college that integrate the sciences; that are investigative, experiential, and issue oriented; that involve students in collaborative study; and that involve appropriate technology.
8. Support community-based recruitment of excellent teachers through efforts such as those that have been used to recruit African-American students through local churches.

Curriculum Development

PHS should undertake the following activities in curriculum development:

1. Develop and fund a national advisory council for education composed of working subcommittees that include a curriculum group and representatives from teacher organizations, scientific societies, and the private and public sectors.
2. Establish an office of educational resources to coordinate and disseminate resources such as curricular materials from Federal agencies, listings of videotapes or speakers, locations of U.S. laboratories available for tours, and scientists available to be mentors and speakers.
3. Initiate and support educational partnerships that allow scientists to participate in the improvement of curriculums in the life sciences.

4. Establish a minigrant program to support teacher attendance at national and regional conventions such as those held by the National Association of Biology Teachers and the National Science Teachers Association.

5. Add a line item to the PHS budget to provide major funding for a PHS initiative in life sciences education; such funds should be supplemental and should not be transferred from the existing, inadequate PHS budget for scientific research.

6. Focus special attention on elementary education, because the early years are decisive for forming beliefs and attitudes about science and efforts directed to elementary students will have multiplier effects in the pipeline that leads to careers in science.

Student Incentives

PHS should provide student incentives through the following mechanisms:

1. Support a national parent-education campaign aimed at "things parents can do" to stimulate and sustain their children's interest in science and in careers that require a science background.

2. Support development, production, and dissemination of life sciences education programs that directly involve children in exploring the physical and biologic world. These programs should use cooperative learning as a central approach for students and encourage parent involvement in the child's learning.

3. Adapt and develop materials to encourage and educate children and adults about careers in the life sciences, and help parents become more effective career counselors for their children.

4. Offer science awards that are available to and within reach of all children and that recognize children who are high achievers in the life sciences as well as students who gradually build their scientific knowledge, skills, and motivation to pursue careers in the life sciences.

5. Support science education efforts that are multilingual and multicultural, and use hands-on science as a way to build a common language of learning.

6. Extend the NIH Minority High School Student Research Apprentice Program, changing the focus of the program to include industrial laboratories, museums, hospitals, health organizations, forestry departments, government agencies, and science museums so that students can learn firsthand about a variety of careers in the life sciences.

7. Support the formation of national science clubs in school and community settings, and of a national science honor society.

8. Develop a nationwide system of "science education agents," whose training must include academic preparation in the sciences; candidates must be able to coordinate resources that link the classroom teacher to new teaching technologies, scientific information, and the scientific community.

Underrepresented and Underserved Groups

PHS should undertake the following activities to attract underrepresented and underserved groups to careers in biomedical and behavioral research and retain them:

1. Collaborate with agencies such as the Department of Education and the National Science Foundation to promote and support programs that make life sciences accessible to all the Nation's citizens.

2. Support career development for underrepresented teachers and teachers who serve large populations of underrepresented students.

3. Support courses that help K–12 teachers use teaching strategies that promote equity in the classroom.

4. Support underrepresented, nontraditional reentry students who want to pursue careers in the life sciences.

5. Adapt the Minority High School Student Apprentice Program to the elementary level and adapt the Minority Access to Research Careers (MARC) Program to the K–12 level.

6. Develop a "Life Sciences for Life" media campaign that uses culture- and gender-sensitive posters, videotapes, public service announcements, and television programming.

7. Conduct national meetings for directors of exemplary life sciences education programs that serve underserved and underrepresented groups.

8. Support research to determine the attitudes of women and minorities toward the life sciences.
9. Attract members of underserved and underrepresented groups to life sciences research by supporting biomedical research in areas that affect those groups.
10. Develop and maintain a detailed, computer-accessible list of life sciences education programs that promote life sciences careers for those in underserved and underrepresented groups.
11. Establish programs that give teachers experience in life sciences laboratories or clinics.

Partnerships and Collaborations

PHS should support partnerships and collaborations through the following mechanisms:

1. Create a mission statement for PHS and its agencies that includes precollege life sciences and public science literacy as priorities.
2. Promote life sciences education and science literacy through alliances, partnerships and coalitions at the local, regional, and national levels.
3. Seek authorization and new funding from Congress for an expanded role in life sciences education.
4. Expand existing programs that promote life sciences education through competitive and noncompetitive mechanisms and provide continuing support for successful partnership programs.
5. Expand the functional responsibility of PHS national and regional offices to include K–12 life sciences education and public science literacy.
6. Continue to work with the Federal Coordinating Council for Science, Engineering, and Technology to coordinate science education activities, adopting elements of successful models at other agencies.
7. Establish a fellowship or scholarship program to support "bridging" people who are familiar with life sciences and education and who can serve as coordinators of outreach programs.

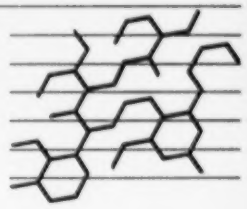
8. Establish nonmonetary rewards that encourage scientists to become involved in life sciences education.
9. Establish graduate training programs that offer outreach education programs as a service activity for students in research or science education.

People Engaged in Science and Technology

PHS should undertake the following activities to involve people engaged in science and technology in partnerships:

1. Emphasize life sciences education as part of the PHS mission by establishing an office of science education and science education policy directly under the Assistant Secretary for Health to guide PHS education efforts and coordinate such activities with outside agencies, institutions, and industry.
2. Establish partnership grants for professional societies, industry, universities, colleges, and other institutions and community groups.
3. Provide grants to scientists who want to help develop innovative education programs for rigorous research into educational methods.
4. Provide incentives in the form of supplemental funding for those who include science education activities in extramural grant applications.
5. Establish regional industry nodes to develop training programs in science education.
6. Expand the Minority Biomedical Research Support Program, the Minority Access to Research Careers (MARC) Program, and the Minority Institution Research Development Program, explicitly including undergraduate students who intend to teach K–12 science or mathematics.
7. Implement payback loans for those entering the field of science education, and provide debt forgiveness related to service in science education.

Appendix B. Conference Speakers



Louis W. Sullivan, M.D.
Secretary, Department of Health and Human Services

I'm pleased to have this opportunity to share a few moments with you. I know you have a lot of work ahead in your working groups and plenary sessions. So tonight I would like to help frame your discussions by mentioning the tremendous need for your deliberations, highlight some of our own departmental efforts, and single out some efforts outside the Department that will help address our national need for greater scientific literacy.

Unless changes are forthcoming, our country is well on the way to becoming a scientific dinosaur. We have heard apocalyptic predictions about the ramifications of our declining national scientific abilities, and we do have much to be concerned about. We must do more—and quickly—to enable our country to continue its many contributions in biomedical research and other sciences. Otherwise we may be witnessing the fossilization of our great biomedical and scientific research enterprise. We are rapidly becoming a scientifically illiterate society. In mathematics and science, American elementary and secondary students recently performed below their counterparts in Japan, China, Mexico, Canada, and Thailand. In one survey, half the adults did not know it takes Earth a year to revolve around the sun.

Why? One reason is that many schools have virtually abandoned study of the hard sciences. For example, 30 percent of high schools offer no course in physics, 17 percent offer none in chemistry, and 70 percent offer no class in earth science or space science. This is shocking—almost unbelievable. At a time when the technological revolution demands more scientific literacy, many of our schools have simply walked away from the challenge of keeping up.

Another reason is that much of our school curriculum has failed to disseminate information. Instead, many schools have become battlegrounds for political and social change. In a recent article, reporter Peter Stothard argued that "since the 1960's, despite thousands of outraged speeches, acres of congressional analysis and sales of millions for conservative educational works such as Allan Bloom's *The Closing of the American Mind,* the national educational

philosophy has continued to attempt social reform, not the spread of knowledge."

A third reason is that as a society we have largely rested on our laurels. For so long we have been the international leader in science and technology. So many people, from policymakers to parents, felt we could set our own pace or even take a holiday from science. That is an incorrect, dangerous assumption, especially because science grows exponentially. A fourth reason is that we have failed to make a career in the sciences attractive to many segments of our cultural mosaic. African-Americans and Hispanics are seriously underrepresented, as are women.

A final reason is that many have allowed antiscientific viewpoints to seize the moment without a strong challenge—such as the beliefs of so-called animal rights activists and the deconstructionists, both of which groups use an understandable and healthy skepticism in science as a patent indictment of all of science's achievements.

At HHS, our work demands an appreciation that biomedical and scientific research is a bridge to a better future. Research will help Americans address some very pressing health care problems—diseases such as cancer, AIDS, sickle cell anemia, heart disease, and many others. On the NIH campus, thousands of research projects are under way. Thousands of other projects are supported by NIH in universities and in corporate laboratories.

Because we must not abandon science, but as a society embrace it more closely, I have made strengthening our biomedical research enterprise a priority at my department. I have a strong commitment because I have come from the biomedical research community. As a physician, I have witnessed the benefits of this research for my patients.

For example, we have developed a Biomedical Research Initiative in PHS. We are working to do the following:

- Strengthen the basic research foundation in the biomedical and behavioral sciences.
- Assure the scientific integrity of our research.
- Educate the public about the importance of animal research and assure animal welfare.
- Promote scientific literacy and improve biomedical science education.

- Improve the intramural research programs of PHS.

One NIH project that interests me is our effort to map the human genome—literally, to understand the information encoded on a human chromosome. This knowledge will dramatically change the medical landscape, revolutionizing the practice of medicine. Gene mapping will help us understand inherited disorders. It could lead to new strategies for the prevention and treatment of more than 3,500 diseases of known genetic origin and to a better understanding of other diseases that have genetic components, such as infectious diseases, cancer, depression, and hypertension.

Thanks to remarkable discoveries in genetics during the past 30 years, we are able to locate individual genes on a chromosome and analyze their chemical components. We can isolate individual genes, and researchers can even dissect DNA at identifiable points that act as markers, mix and match fragments of DNA in various organisms, and grow large quantities of these fragments in bacteria.

Because of its potential impact on our world, and because of the Herculean nature of the project, the London *Economist* has called this "big science," and it surely is. You can see why Nobel laureate Walter Gilbert has said the Human Genome Project is the Holy Grail of genetics. But perhaps Norton Zinder of Rockefeller University is closer when he calls it medicine's Rosetta stone.

The initiative is under the able direction of Nobel laureate Dr. James Watson, codiscoverer of the double helix in the DNA molecule. He predicted this program could produce a chromosome map within 5 years and a complete map of the sequence of all the DNA on the chromosomes in 15 years.

The business and research communities have already recognized the importance of this research. On January 22, 1990, the *Washington Post* reported that the Industrial Research Institute, in a national survey of 257 research-intensive firms, had found these firms gave the Human Genome Project the highest priority of the "big science" projects, higher than the Hypersonic Airplane, the Space Station, the Strategic Defense Initiative, and the Superconducting Supercollider.

In the President's new budget we will continue to emphasize strengthening biomedical and behavioral research at NIH and ADAMHA, agencies of PHS. Because of the indispensable, undeniable need for this research, we are requesting $9.8 billion for these activities in fiscal 1992, an increase of $581 million or 6.3 percent over

last year's funding levels and a $2-billion or 25-percent increase since I offered my first budget at HHS.

Within that budget we have allocated $513 million for science education and research training. More than $345 million will be used to fund our well-established and successful National Research Service Award Program.

Included in this program is the MARC Honors Undergraduate Research Training Program, which focuses special attention on encouraging and supporting minority undergraduate students as they pursue careers in science.

At the precollege level, the Department has allocated $21.8 million for education and training, almost $10 million of which is devoted to supporting the NIH Minority High School Student Research Apprentice Program, which pairs talented minority students with PHS scientists who offer hands-on research experience and serve as mentors for students. The Department is spending more than $9 million for new programs that will expand efforts to enhance teachers' and students' knowledge of the life sciences and encourage further alliances between the scientific and education communities to improve science. And in 1989, Dr. Mason established the PHS Working Group on Biomedical Science Education, charged with developing a life sciences education initiative and with ensuring an adequate pool of well-trained biomedical scientists. One of their recommendations was this very conference.

There are other HHS efforts, and I know that you will examine each very carefully. I am hopeful your work will enable us to expand our efforts and build more partnerships with efforts in the private sector. Let me take a moment to examine some private initiatives that hold promise.

I spoke last month at Xavier University in New Orleans, which has a remarkable initiative to increase the number of minority students who will pursue science careers. The program offers an educational pipeline that begins to identify promising students as early as junior high and provides various means of support until they enter higher education. There is a wonderful discussion of this program by two of the campus's outstanding educators, J.W. Carmichael and John Stevenair, in the latest *Issues in Science and Technology*. I recommend it as important reading on this subject.

Timothy Ready and Herbert Nickens of the Association of American Medical Colleges wrote an article in the April 1991 issue

of *Academic Medicine*, "Black Men in the Medical Education Pipeline: Past, Present and Future." They mention several schools that have pioneered efforts to develop and retain undergraduate premedical students, such as the Tulane University School of Medicine, the Baylor College of Medicine, the Charles Drew Postgraduate School, and the University of Illinois College of Medicine. Each worked with local elementary and secondary schools to increase the size of applicant pools, with early outreach efforts and an emphasis on stimulating an interest in science in minority students.

And at the University of California, Los Angeles, chemistry and mathematics professors work with local elementary and secondary students to make science more interesting and relevant—with "Math Passion Days" in the schools and community outreach plans. They believe science is compelling to students if it is properly presented. Indeed, it is. And if we are to address scientific illiteracy, we must reenergize the scientific community. We need to open the doors of the laboratories and unlock the ivory towers. Our scientists need to explain themselves and stimulate interest in their field. Such efforts may be an even more important legacy than their current research. I hope this conference will encourage every scientist and health professional to work in the community with students of all ages to increase scientific literacy.

Scientific illiteracy is one of our most important national problems, with long-lasting effects for our Nation, perhaps the planet. Your work as individuals, scholars, and scientists at this conference can help shape our future and our thinking. I look forward to reviewing your recommendations and hearing of your discussions. Thank you for sharing a few moments with me, and Godspeed to you in your work.

James O. Mason, M.D., Dr.P.H.
Assistant Secretary for Health
Head, U.S. Public Health Service

Last night Dr. Sullivan stood before you and assured you of his concern and support and that of the President and the Bush administration. Today, I'm here to assure you that you have my full support. PHS is ready, willing, and able to be part of the efforts that increase science literacy and ensure an adequate pool of well-trained biomedical scientists who will enable this Nation to retain its international prominence and meet its internal needs.

We have a superb tradition for use as a template. Many great moments in medicine are products of American ingenuity. Since the end of World War II, 101 scientists worldwide have received the Nobel Prize in medicine or physiology. More than half, 64 of the 101, were Americans.

Unfortunately, recent data show we're flirting with danger. If present trends continue, America will be ill prepared to meet the requirements of a competitive scientific society during the 21st century. We're losing our international preeminence in science and math. We've spawned a generation of scientifically illiterate citizens who are poorly equipped to function in the most technically challenging environment the world has ever known. While Japan has doubled its technical work force in the past 2 decades, our country will not produce enough scientists and engineers to meet its work force needs. It's estimated that by the year 2000 the demand for biomedical scientists will be twice the current level of Ph.D. production. We're looking at a deficit of 400,000 scientists and 275,000 engineers by the year 2006.

Responsibility for the decline is broadly shared. It has spread like water on a flat surface throughout our society—from schools to government to parents and, of course, to students themselves. Although for years America's schools have been posting signs on science classroom doors, "Free knowledge Monday through Friday—bring your own container," too many students have passed up the bargain.

When American adults were asked to answer 7 relatively simple questions like, "Which travels faster, light or sound?" and "Which is smaller, an electron or an atom?" only 15 percent answered the 7 questions correctly.

In a recent international science achievement survey that compared students in the United States and 15 other countries, our high school seniors finished in the bottom fourth in calculus and algebra, in the bottom third in physics and chemistry, and dead last in biology. Similarly, in a biology test administered to 12,000 high school students, 30 percent of the students who hadn't taken a biology course did as well as or better than 40 percent of those who had. Only about 10 percent of junior high students and 40 percent of high school students can be considered moderately versed in science—able to logically think through elementary scientific procedures and data.

Poor student performance and lack of interest in math and the sciences don't end with high school graduation. According to a 10-year study of college freshmen, interest in the biologic and physical sciences declined between 1978 and 1988 while interest in the humanities, business, and the social sciences increased. Only 6 of every 4,000 seventh graders—5 boys and 1 girl—ultimately will receive a Ph.D. in science or engineering if present trends continue. Only about 5 percent of 22-year-olds earn bachelor of science degrees—and only about 5 percent of them go on to earn Ph.D.'s.

Poor student performance is translating into declining professional aptitude and competence. America's premier position in scientific research and development and its marketplace competitiveness in these fields are in jeopardy. Although U.S. inventors have increased the number of successful patent applications, foreigners are acquiring U.S. patents at a significantly higher rate. The proportion of patents awarded to foreigners rose from 30 percent in 1970 to nearly 50 percent in 1987. During this same period, the U.S. share of the world high-tech market dropped from about 50 percent to 40 percent. By 1986, falling exports in high-tech goods actually contributed to the U.S. trade deficit. During the same period, Japan doubled its share of the world market.

Now, these trends are only the tip of the iceberg—early warning signs. We're headed for a real crisis unless we turn around. But we're not totally in the dark. We know we need to improve school curriculums. In the lower grades, science must be given higher priority. In the upper grades, more science needs to be offered. Nearly 30 percent of our high schools offer no courses in physics, 17 percent offer none in chemistry, and 70 percent offer none in earth or space science.

To our credit, our schools generally increased math and science offerings in grades 7 to 12 between 1977 and 1987. However, despite the increased availability of math and science courses, data suggest fewer students are taking them.

Quantity of instruction isn't the only consideration. Quality must also be part of the equation. More than half the third-grade students and four-fifths of seventh-grade students never went on a field trip with their science class. Half never did oral or written reports or conducted independent experiments. Learning science is supposed to be not an exercise in rote memorization but an exploration of how the world works.

According to a recent report by the National Research Council, "Current instruction in biology ironically seems designed to snuff out interest in science. It fails to relate the life sciences to the experience of living."

We know we need to reach down into the early grades and take advantage of children's natural interest in themselves and the world around them. The *Washington Post* recently told about a kindergarten class that visited a local police station, where they saw the photos of the 10 most wanted men. One child pointed to a picture and asked if it was really the picture of the person wanted. "Yes," replied the policeman. "Well," inquired the youngster, "why didn't you keep him when you took his picture?"

We could ask ourselves a similar question: Why don't we keep our kids' interest when we have it? Waiting until children are in junior high or high school is too late. By then, according to a National Science Foundation survey of seventh graders, fully half already have no interest in science.

We know we need to attract more talented young people into the teaching profession, particularly as math and science teachers. America's schools will need to hire about 160,000 teachers a year between now and the year 2000. Yet we're graduating only about half that number. Even more startling, for every math or science teacher that enters the profession 13 leave.

We know we need to do a better job of training teachers. Many math and science teachers, particularly in the lower grades, have never had a college-level course in math or the life sciences. Only 33 percent of elementary school teachers, 22 percent of middle-school teachers, and 29 percent of high school teachers have adequate preparation in science.

We know we need to do more to retain talented teachers. Curriculum, no matter how good it is, doesn't teach itself or come to life on its own. Capable, caring teachers are needed to communicate the excitement of science to students.

We say that our children are our most important product and our most valuable resource, yet in some cities we pay garbage collectors better than we pay schoolteachers. When a teacher has a family to support, there's a limit to the dedication and sacrifice he or she can afford to make. I'm not demeaning the importance of garbage collection. Good science teachers have many opportunities to go elsewhere, and they do.

I can testify to the value of a talented, dedicated teacher. I had a high school math teacher who inspired 90 percent of his homeroom students to go on to graduate degrees; he was a magnet teacher. We need to free teachers to teach. Too much valuable time is spent filling in for parents, disciplining kids, and instructing them in social skills.

We need to correct the underrepresentation of women, minorities, and disabled people in science. Only 8 percent of bachelor of science and engineering degrees and 4 percent of Ph.D.'s are awarded to African-Americans and Hispanics. While 20 percent of our population is made up of those in minority groups, only 8 percent of scientists and engineers are minorities. A high proportion of these are Asian-Americans. Only 13 percent of scientists and engineers are women.

Finally, we know we need to improve the image of math and science. To paraphrase Rodney Dangerfield, "they don't get no respect" from many young people. Math has the reputation of being hard and understandable to an elite few. Science has the reputation of being boring, fodder for eggheads and nerds.

One student wrote, "Win a championship football game in high school and you'll likely get an assembly in your honor, with cheerleaders screaming. Win a science fair and you're lucky to get your name broadcast over the PA system to sleepy classmates."

We'd like to see more of our schools capitalize on the positive aspects of the peer pressure we know motivates young people. We'd like to see more schools awarding "letters" in academics. We'd like to see more students aspire to National Honor Society membership. We'd like to see advanced biology honor rolls in every school newspaper and see math and science clubs flourish. We'd like to see science fairs expanded into citywide events, academic competitions sponsored, and winners recognized by the student body.

There's plenty of evidence that these things work. In central California two chemists, Nate Skinner and John Di Benedetto, formed a group of 100 volunteers called Rediscovery Educational Activities Create Tomorrow's Scientists (REACTS). They've put together a traveling science show for preschool, elementary, and high school students. By combining amazement and amusement, they're teaching a generation of youngsters that science can be exciting and fun. According to Dr. Skinner, the interest stays with these kids long after they leave the classroom. He tracked down 14

students he had taught 12 years earlier in the fourth grade. Of the 14, 7 had entered scientific careers.

This can happen in all our schools. Exciting curriculums with up-to-date textbooks, talented teachers, and curious students who are challenged to learn and do well aren't a wish list. They're doable all across America—in the words of Longfellow, "in every Middlesex village and farm."

This conference is a forum in which you experts are asked to provide direction to future PHS initiatives. We want—we need—your input. Our resources are substantial but not unlimited. We want to make the best use of them. Help us develop a comprehensive set of recommendations that will become the foundation of a life sciences education action plan. It would complement and build on existing Federal, State, academic, and private activities rather than duplicate any of them.

Your recommendations will be integrated into a comprehensive action plan that will be implemented by PHS in coordination with its many partners. We want direction on ways the Department can work with communities to strengthen and support both the science education of students and the basic science literacy of the American public.

You are the experts, the teachers, the students, and the school administrators. You are the scientists and the representatives from private industry and the media. It's essential to the success of the action plan that it reflect your unique perspective, experience, and expertise—and that it complement existing Federal, State, and private programs.

Because you have the practical, hands-on experience, you need to tell us what works and what doesn't. You need to tell us how to fine-tune old programs and frame complementary new ones; how to make curriculums more interesting and relative to real-life experiences; and how to enlist and keep the best math and science teachers at all levels of our education system.

PHS has taken the first steps. Through our agencies and with the help of our talented cadre of well-trained intramural and extramural scientists, PHS is supporting a variety of science education activities. PHS is actively involved on the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology. PHS organizations have signed a memorandum of understanding with Dr. Allen Schneider,

program director of the Office of the Assistant Secretary for Education Research and Improvement, Department of Education, to provide partial funding for two of that department's research centers on science education. We are actively pursuing similar collaborative projects with the National Science Foundation, the Department of Energy, and other Federal departments.

In 1990, NIH collaborated with the National Aeronautics and Space Administration to develop a curriculum supplement, "Human Physiology in Space: A Program for America." ADAMHA and NIH have created the Science Education Partnership Awards to recruit talented students into the biomedical and life sciences educational pipeline. NIH sponsors a program called Biomedical Research Advancement: Saturday Scholars. The Science Alliance was created to establish linkages between PHS scientists and elementary educators. We have implemented adopt-a-school programs. The Centers for Excellence Program was designed to strengthen our capacity to train minority students in the health professions. These programs are only a start. We're looking to you to tell us where to go from here.

Helen Keller said, "Science may have found a cure for most evils; but it has found no remedy for the worst of them all—the apathy of human beings."

There's no apathy in this room, otherwise you wouldn't be here. Instead, there's a lot of energy and creativity. That's exactly what we need—not only from you, the leaders in today's science education community, but also from the coming generation of science-literate men and women we must inspire and educate. I challenge you to give form and direction to the PHS effort. We are eager to work with you in a national effort that will ensure our Nation's preeminence in science education and scientific achievement. I look forward to receiving the ideas and recommendations that will flow from you over the next 2 days.

Bernadine P. Healy, M.D.
Director, National Institutes of Health

NIH is a national treasure, and I am honored to have been confirmed as its new director, to do a job so enormously worth doing. The philosopher-essayist of modern medicine, Lewis Thomas, put it well: "As institutions for human betterment go, NIH is a standing proof that, at least once in a while, government possesses the

capacity to do something unique, imaginative, useful and altogether right."

For 100 years NIH has been driven by the mission to acquire new knowledge of human disease for the betterment of all our citizens. With that mandate NIH has nourished a science base that reaches out to more than 1,700 universities and research institutions and enlists the labors of more than 100,000 people working at some level on NIH-funded activities.

In my professional life I have been privileged to experience directly the strength of this great diversity. I have been involved with Harvard, first as a medical student and most recently as an overseer. For many years I was fortunate to be a part of Johns Hopkins as a scientist, a clinician, and a professor of medicine. I also have had the challenge of leading the expansion of Cleveland Clinic Foundation Research Institute, which included developing new programs in molecular and cell biology, protein chemistry, and bioengineering, all targeted to major diseases.

These experiences have shown me how effectively NIH can marshal the strengths and talents of many excellent institutions with different cultures for a common goal. The strong Federal support of biomedical research through PHS agencies such as NIH has enabled science to flourish largely unfettered, promoted diversity of ideas, and fostered healthy competition and cooperation.

And yet, as we enter the final decade of this Health Century, it is apparent the sciences as a career choice are losing their magnetism for U.S. youth. It is a chilling paradox of one of the world's most advanced countries, whose successes have depended on technological and scientific achievements, that we could be rearing a generation of technical illiterates who will manage, not create, tomorrow's innovations.

The potential future scarcity of scientific investigators is particularly disturbing at a time when science has never been more effective, its discoveries more exciting, its Federal monetary support greater. In the 1990's and beyond, in the era of what is termed space station technology, the frontiers of life science appear limitless. We can expect to benefit from regeneration of damaged spinal cords, learn the molecular basis of myriad physical disorders, and see the repair of defective human genomes.

This is the future of biomedical research and technological innovation, and it depends first and foremost on talent—on the biomedical brainpower being developed now for tomorrow.

A major question as we look toward biomedical science in the next century is whether the sparks of genius will be there. To ensure that they are, our first priority is building and maintaining a human talent base—the quality of our science is no better than the quality of our scientists. And since science is about brainpower, not brawn or pedigree, it must attract gifted individuals of all types. Talented women and minorities should view careers in biomedical research as the essence of equal opportunity, not just because it is proper, moral, and legal, but because science needs their brains, their perspectives, and their contributions.

NIH gives more than $300 million annually to support about 12,000 graduate students and postdoctoral fellows. But the success of this effort ultimately depends on the number of students in primary and secondary education who choose science as a career pathway.

In 1986, NIH began to focus on the importance of science education at the precollege level. That year a coalition called Partners in Discovery—made up of 14 pharmaceutical companies, the Howard Hughes Medical Institute, and NIH—was formed to stimulate young people's interest in biomedical research careers. In fiscal 1992 NIH proposes to continue and nurture its Biomedical and Life Science Education Program. The program is designed to complement general science and math education initiatives spearheaded by the National Science Foundation and the Department of Education. We see this as a vital effort to be performed in conjunction with other agencies.

Within the Office of the Director, the Director's Discretionary Fund enables NIH to respond quickly and effectively to unexpected research needs, emerging priorities, and interinstitute research opportunities. This fund has been valuable this year in providing resources to launch preliminary efforts relevant to science education and related projects.

Also in 1992, the new NIH Office of Science Education Policy, within my Office of Science Policy and Legislation, is being established to plan, develop, direct, and coordinate a comprehensive science education program that strengthens NIH efforts to attract young people to biomedical science careers and to improve science

literacy in adults and children. Through this new office, and working as a team with other PHS agencies, NIH will initiate, oversee, and make policy decisions on special science education grant programs.

A primary focus will be the development of hands-on laboratory experiences for school children at the elementary through high school levels. NIH will initiate life sciences education activities targeted to students in kindergarten through college, their educators, their parents, and the public, giving junior and senior high school students and teachers hands-on research experiences and enhancing curriculum development from kindergarten through high school.

One new program being piloted this fall is the BRASS Program (Biomedical Research Advancement: Saturday Scholars). As envisioned, each year BRASS will give about 100 middle-school students in the Washington, DC, metropolitan area a chance to participate in a 6-week Saturday morning science program held on the NIH campus and taught by PHS scientists. The BRASS Program is the pilot for a model we hope to develop and use in medical and dental schools across the country. During the academic year, we will offer seminars, hands-on laboratory experiences, and field trips.

This is just a small part of our commitment to public science literacy, because biomedical researchers don't spring forth full-blown—educated and motivated. They come from society, and the rate at which they come depends on how science is viewed by people whose jobs and interests do not directly involve the workings and issues of science.

Despite their perspective (for or against), all components of society influence and benefit from medical and scientific brainpower—universities, government, industry, and the public. We all are at risk if the scientific brainpower of the next century is in jeopardy.

The Government would do well to consider creating an "intellectual capital protection agency" to reassess the value of a true spirit of enterprise, which is the essence of research and development. Industry, which carries the advances of science to the public and serves the country's economic base, can exercise its enormous political influence nationally and locally on behalf of science and education. And from many fronts, strong positive public support must be gathered for medical research and the laborers who make medical

advances happen. Ultimately it is the public who can make a difference.

As a people and a country, we have not always appreciated intellectual achievement, considering the success such achievement has brought us. Our consciousness must be elevated to recognize the value of scientific capital and precious human talent. In that respect, the future of medicine and science for this country will be determined by society's basic commitment to education—specifically, life sciences education—and our willingness to shift the focus to the hopes and dreams of tomorrow, which means a focus on our children.

This is where you come in. Our schools and universities are the keystone of our science base, but they must focus on the needs of the individual. As the cradle of new talent, they must nurture young scientists and provide them with mentors. The individual is the limiting factor in science and medicine, and it is the human factor that attracts many into the field.

We all know the power of this human factor—the mentor, the wise and faithful counselor. Mentors come in all forms but they all do the same things—guide, instruct, and inspire. They may come along at any time; as an older sibling showing a younger one how to perform a task, a parent who instills a passion for intellectual achievement, a teacher who inspires by great expertise and talent, or a guide and counselor who shows the proper path to follow.

In these forms, the mentor is the individual who personally inspires one to reach a little higher. As we work within the giant science base with its many dimensions, the challenge is to keep the focus on the individual—on creative minds that innovate and mentors who inspire. As we look to tomorrow, we must all be mentors to the children—nurture their talents, give them opportunities, be their guides, and challenge their brains to question and make the discoveries that will enable both science and the Nation to be the best they can be.

In 1952, researchers R. H. Knapp and H. B. Goodrich published *Origins of American Sciences,* a book that surveyed the undergraduate origins of American scientists. "At this juncture of history," they wrote in conclusion, and it is equally true today, "science may justly claim the prime attention of scholars, statesmen, and industrialists alike; for almost any prospect of the future must envision the further advance of scientific knowledge, together with its revolutionary

impact upon human affairs, while the current problems of our civilization require in the most pressing sense the resources of science for their solution."

William F. Raub, Ph.D.
Deputy Director, National Institutes of Health

I appreciate the opportunity to join in this conference and to sample firsthand the knowledge and enthusiasm you all have brought to it. We have heard a series of distinguished speakers present sober assessments of the state of science education and rally us with ideas to improve it. We have exchanged experiences and insights augmented by a luncheon period of fine food and fellowship. And now, as waves of postprandial somnolence lap gently upon the shores of our consciousness, my job is to keep us awake.

I propose to do that by discussing public literacy in science, mathematics, and engineering—long odds, to say the least. How important is it that nonscientists, whether young people or adults, be conversant about science concepts in general and their everyday technological manifestations in particular? Will our society be compromised somehow if the average citizen cannot relate effectively even at a superficial level to science and scientists? Or will we do just fine even if John and Jane Q. Public routinely encounter nothing more technologically challenging than prime-time television and the tabloids at the supermarket checkout?

Imagine with me the following scene. The high school gymnasium is bedecked in crepe paper streamers for the 20th reunion of the Class of 1971. The old grads are greeting one another with enthusiasm and nostalgia. Suddenly, in front of the gymnasium appears a stretch limousine and out steps Bozo, the dumbest guy in the history of the school.

His classmates gather around him excited, and one of them shouts, "Bozo, the rumors really are true—you're a millionaire! How did you do it? You never passed a math test in your life!"

Bozo gazes earnestly into the awe-filled countenances of his friends, smiles shyly and says, "Well, I make money buying and selling things. For example, if I buy an item for $10, I sell it for $40. That way, I always make 4 percent profit."

That story always amuses a sophisticated audience like this one. But I invite you to try it on a group of laypeople; you're likely to

receive a mixed reaction. Moreover, if you question them about their responses, you might elicit some surprising views. One guy might say, "I don't get it. Four percent sounds okay to me," while another might say, "What an idiot! He buys at $10 and sells at $40. He makes 30 percent profit and doesn't know it!" At the coffee break this afternoon, we'll take a poll as to whether the right answer is 300 or 400 percent.

But is that story really representative of any significant fraction of our society? A skeptic might say that all I've done is tap into math phobia—that other aspects of science and technology are better understood by the typical person in the street. Well, let's consider three science topics that will be prominent throughout the 1990's.

The first is gene therapy. During the past 2 years, scientists at NIH have ushered in a new era in medicine. They are the first ones—and so far the only ones—to have placed foreign genes in human subjects. One line of experimentation treats a rare inherited enzyme-deficiency disease by inserting a copy of the normal gene into a sample of the patient's own white blood cells, growing a large quantity of these genetically engineered cells in a laboratory vessel, then infusing them into the patient, thereby supplying copies of the normal enzyme.

The other line of experimentation attacks an advanced cancer by surgically removing selected white blood cells from the patient's tumor, equipping these tumor-infiltrating lymphocytes with a gene that makes them potent killers of cancer cells, cloning the super-charged white blood cells in the laboratory, then injecting them into the patient so they can home in on the cancer with all their newly acquired lethal force.

These techniques are being improved and extended rapidly, and they surely will be applied to treat many different genetic diseases before the end of the century. But, ladies and gentlemen, I ask you: Will this revolution in molecular medicine be appreciated by people who think that gene therapy means sewing a patch on your Levi's 501's?

The second example is deep-space astronomy. Recently, the Hubble telescope was rocketed into Earth orbit and, despite its much-ridiculed astigmatism, is producing more informative images of celestial objects than do ground-based observatories. The 1990's will see more such eyes in the sky operating at various spectral bands and detecting signals from sources so many light-years away that

we will scarcely comprehend the distances involved. Will this mean anything to folks who think that a light-year is something that has fewer calories than a regular year and is less filling and tastes great?

Third, consider high-energy physics. Congress now is debating how much money to invest in the Superconducting Supercollider. This giant atom smasher is intended to provide heretofore unavailable glimpses into the realm of subnuclear forces and particles and take us another step closer to the elemental essence of matter and energy. Will this great scientific instrument and the associated research be financed adequately by taxpayers who think that a supercollider is the winning car in a demolition derby?

The Music Man, Professor Harold Hill, said it right. "We've got trouble, my friends, right here in River City"—and, to tell the truth, in every city, town, and rural community of the United States if we allow such gaps in knowledge to happen.

So, what can we do? Can we expect to make any inroads or are we reduced to viewing with alarm? I don't pretend to have the ultimate answer, but I see two avenues worth exploring.

Let's call the first approach *Science is Useful!* The idea is to highlight how and why science and technology are inextricable parts of many things we take for granted in everyday life. If we can instill a deeper appreciation of our debt to the scientists and engineers who have gone before, perhaps that will kindle a public passion for the additional contributions their successors might produce.

For example, consider vaccination. Sometime between the first months of life and entry into kindergarten, almost every child in the United States is inoculated against a variety of diseases that plagued earlier generations and produced horrendous mortality levels, especially among infants. Along with sanitation, such prophylaxis is the centerpiece of public health. Most of us rarely give vaccines a second thought. Yet, from my experience, the average layperson seems to have only a superficial knowledge of how vaccines come to be or how they protect us.

And, to paraphrase Pogo, the enemy may be us. We probably haven't told nonscientists enough in simple terms about antigens, antibodies, cell-mediated immunity, immunological memory, and the host of other relevant concepts. We surely haven't explained the indispensable role of laboratory animals in the development and testing of vaccines. We haven't discussed adequately the science and ethics of vaccine trials in humans, noting especially the extra burden

of ensuring safety because, unlike drugs (which are administered primarily to the sick), vaccines almost always are intended for the healthy. In short, can't we do more to ensure that public literacy about vaccines and disease is materially more substantial than the medieval view of talismans and evil spirits?

Think about it for a moment. It's scary. The concepts are isomorphic: talisman is to evil spirit as vaccine is to disease. Sounds like an SAT question. Let's be sure folks understand vaccines more deeply than that.

Turning to another example, consider the internal combustion engine. It powers the automobiles that do so much to define our lifestyles, yet its ubiquity can make us overlook how much contemporary science and engineering are devoted to improving or replacing it. The average layperson probably doesn't know about how materials scientists seek new metal alloys and ceramics with which to construct lighter weight and more fuel-efficient engines. We can do more to call attention to the search for cleaner burning and therefore more environmentally compatible fuels or to the increasing use of microcomputers to enhance engine performance. We haven't broadcast a compelling vision about the prospects for artificially intelligent robots in engine assembly and all manner of other manufacturing situations, as well as the need for research and development to make that prospect a reality. Ladies and gentlemen, taking vaccines for granted is bad enough. Surely we can't afford to let society ignore the technological correlates of Fahrvergnugen!

But we need not put all our eggs into the basket of utilitarianism. Let's consider a parallel approach called *Nature is Amazing!* I would wager that everyone here has experienced many times a "Wow! Gee whiz!" feeling upon seeing or learning about some natural process such as the folding of a protein, the conducting of a nerve impulse, or the developing of an embryo. If we can capture and communicate that sense of wonder and excitement to nonscientists, we might have an easier job in promoting public literacy about science and technology.

Each of us undoubtedly has many topics that fascinate us for one reason or another. Mine come from various sources, but in general they manifest my training as a mammalian physiologist. As Maria sang in "The Sound of Music," "these are a few of my favorite things..."

First, the lungs (I throw this in to ensure I mention something "inspiring"). We all know their primary function is to facilitate the exchange of oxygen and carbon dioxide between the outside air and the blood. The reciprocal handoff occurs in millions of tiny air sacs called alveoli working in parallel as blood surges through capillaries so narrow that the red cells often must move in single file. The alveoli alternately fill and empty of air as the result of a bellows action that is effected by the chest muscles and controlled by a hierarchy of brain centers.

A critical factor in the efficiency of gas exchange in the lungs and elsewhere is the surface area. For example, as every parent of teenagers knows, damp bath towels dry faster if hung neatly in an extended fashion on a clothesline than if left crumpled up in a ball on the bathroom floor. What amazes me about the human lungs is that Nature has packed into our chests a total alveolar surface area that is roughly equivalent to that of a tennis court. Think about that anatomic marvel the next time you feel some discomfort behind the sternum. It probably will be heartburn; but, then again, it might be Jimmy Connors at match point.

My other example for today is the kidneys, the twin organs that are attached to the back of the abdominal wall and that are shaped like swimming pools. Kidneys cleanse the blood of the byproducts of metabolism and other unwanted substances. This is a vital and complicated function; as they say down at the toxic dump, waste is a terrible thing to mind.

During the last part of the 19th century and the early part of the 20th, physiologists were perplexed at how the kidneys were able to determine which substances to excrete and which to retain. Even synthetic organic chemicals that no living system ever has encountered before are usually excreted with no apparent difficulty. Elaborate theories were postulated to explain the differential recognition and transport, but with little success for a long time.

The answer proved to be breathtakingly simple. The millions of filtration units called nephrons filter from the blood essentially all of the blood's soluble, nonproteinaceous substances and then take back only the ones the body wants—and these, only in the quantities the control systems dictate. This ingenious design helps ensure a stable internal milieu even in the face of a changing and unpredictable environment and, therefore, has proved to be evolutionarily robust. And, as in the case of the lungs, note the functional advantage

of using parallel processing and packing an extraordinary surface area into a small volume.

I recently put this concept into action in a nonphysiological setting. As my teenage son was unenthusiastically starting an archeological expedition into his bedroom, I suggested that the cleanup might go better if he were to apply the principle of renal filtration. So, he proceeded to remove almost everything from the room and then put back only the things he wanted. The transformation was remarkable. However, the upstairs hall now looks like a dysfunctional bladder. Time for another physiology lesson when I get home.

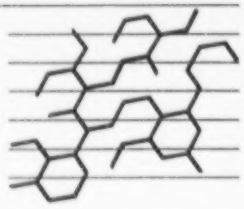
In closing, I urge that we think of all the ways we can to let the utility of science and the wonder of Nature work for us as we exhort students and adult laypersons to enhance their literacy. The richness of material is mind-boggling. We are limited only by our creativity in telling them about what turns us on.

But, as the following cautionary tale suggests, let's keep our expectations realistic. A father was remonstrating to his 16-year-old son over the latter's modest academic achievement.

"Why, when George Washington was your age," the father said, "he already was a skilled surveyor."

"True," the son replied, "and when he was *your* age, he was President of the United States."

Appendix C. Conference Steering Committee and Subcommittee Chairs



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